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ABSTRACT

The purpose of the study was to hypothesize and test a causal model of continuation in the mathematics study sequence. The causal model hypothesized (a) direct effects from parent attitudes and perceptions to student attitudes, spatial visualization skills, and mathematics achievement; and (b) direct effects from student attitudes, spatial visualization skills, and mathematics achievement to continuation in the mathematics study sequence. Stepwise regression analysis was used to trim the hypothesized causal model for each of males and females. The resulting reduced causal models were interpreted for consistency with previous research and were tested by the method of reproduction of correlation coefficients. Data were obtained from a longitudinal study of 457 students who participated as eighth graders and, again, as twelfth graders. (References, tables, and figures are appended.) (Author)

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Causal Models of Continuation in the Mathematics Study Sequence

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Abstract

The purpose of the study was to hypothesize and test a causal model of continuation in the mathematics study sequence. The causal model hypothesized (a) direct effects from parent attitudes and perceptions to student attitudes, spatial visualization skills, and mathematics achievement; and (b) direct effects from student attitudes, spatial visualization skills, and mathematics achievement to continuation in the mathematics study sequence. Stepwise regression analysis was used to trim the hypothesized causal model for each of males and females. The resulting reduced causal models were interpreted for consistency with previous research and were tested by the method of reproduction of correlation coefficients. Data were obtained from a longitudinal study of 457 students who participated as eighth graders and, again, as twelfth graders.

Causal models of continuation in the mathematics study sequence

The purpose of this study was to hypothesize and test a causal model of continuation in the mathematics study sequence that would relate the affective and cognitive variables that are associated with continuation in the mathematics study sequence. After a considerable review of the literature, the variables chosen were mathematics achievement, spatial visualization, student attitudes toward mathematics, parent attitudes toward math as a male domain, and parent perceptions of their child as a learner of mathematics.

Continuation in the mathematics study sequence, or mathematics participation, has been the subject of several studies. Armstrong and Price (1982) found positive attitudes toward mathematics, career aspirations, and parental, teacher, and counselor encouragement to affect math participation. Lantz and Smith (1981) found confidence in math ability, liking for math, usefulness of mathematics, and perception of parental encouragement significantly correlated with math participation. They also found objective appraisals of mathematics achievement as well as subjective comparisons of math ability to be predictors of math participation. Sherman (1979, 1981) and Meece, Parsons, Kaczala, Gott, and Futterman (1982) supported the effect of math achievement on math participation. Sherman

(1981) found spatial visualization skills to be the most important factor for female continuation in the mathematics study sequence; it was the least important factor for male continuation in the mathematics study sequence.

In order to posit a causal relationship among the variables, a one-way direction of causality had to be specified. A number of studies had supported various correlational relationships between parent attitudes and perceptions and student attitudes (Hill, 1967; Parsons, Adler, & Kaczala, 1982; Poffenberger & Norton, 1959; Wilhelm & Brooks, 1980). Poffenberger and Norton (1959) further indicated that student attitudes toward mathematics were culminative phenomena and were developed in the home in some cases before the child begins school. Thus, a direction of causality from parent attitudes and perceptions to student attitudes was hypothesized.

A direction of causality from parent attitudes and perceptions to each of student mathematics achievement and student spatial visualization was also hypothesized. Tsai and Walberg (1983) found that family background was influential in the learning of mathematics. Meece et al (1982) suggested that early socialization experiences influence the development of different spatial and math abilities. Fennema and Sherman (1977) supported the belief that socio-cultural factors are highly important concomitants of sex-related differences in mathematics achievement and spatial visualization. The role of parent as socializer was suggested by both Fennema and Sherman (1977) and Meece et al (1982).

The direction of causality among student attitudes, math achievement, spatial visualization skills, and continuation in the mathematics study sequence was hypothesized to be from each of the student attitudes, from mathematics achievement, and from spatial visualization skills directly to continuation in the math study sequence. The integrity of the hypothesized model was insured by the longitudinal design of the study in which data on attitudes, achievement, and spatial visualization skills were gathered during the students' eighth grade and continuation in the math study sequence was measured at grade twelve.

Parsons (1980) reported that the sex of the child had a definite effect on the parents' perceptions of the child's mathematics performance. Since the relevance of sex-differences to mathematics related variables is well documented, a decision was made to investigate the hypothesized causal model for males and females separately.

Method

Procedure

As a result of an intensive search of the literature, a causal model of continuation in the mathematics study sequence was hypothesized. The independent variables selected for the model were mathematics achievement, spatial visualization skills, student attitudes toward mathematics, parent attitudes toward math as a male domain, and parent perceptions of the child as a learner of mathematics. In order to test the hypothesized causal model in the exploratory stages of the

study, a decision was made to obtain data-guided reduced causal models, one for males and one for females, by the method of stepwise regression analysis. The resulting reduced causal models were considered to represent a pattern of direct effects among the variables in the reduced causal models. The reduced models were interpreted for consistency with previous research and were tested by the method of reproduction of correlation coefficients.

Subjects and variables

Data were obtained from a longitudinal study of 457 students, 213 females and 244 males, who participated both as eighth graders and again as twelfth graders. During the eighth grade, data were collected on mathematics achievement, spatial visualization skills, student attitudes toward mathematics, parent attitudes toward math as a male domain, and parent perceptions of their child as a learner of mathematics. During the twelfth grade, data were collected on the highest level of high school mathematics course successfully completed or under completion that year.

Mathematics achievement was measured by the national percentile rank attained by the student on one of the following standardized achievement tests: California Achievement Tests (Tiegs & Clark, 1970); Comprehensive Test of Basic Skills (California Test Bureau, 1973); Iova Test of Basic Skills (Hieronymus, Lindquist, & Hoover, 1971); Science Research Associates Assessment Survey (Thorpe, Lefever, & Naslund, 1974);

and Stanford Mathematics Tests (Madden Gardner, Rudman, Karlsen, & Merwin, 1973). Due to time constraints imposed by the school districts, it was not possible to test all students with the same instrument. Davis (1964) states that the percentile ranks for tests given to large groups randomly drawn from the population are reasonably comparable.

Spatial visualization skills were measured by the Space Relations Test (Form T) of the Differential Aptitude Test (Bennett, Seashore, & Wesman, 1972).

Student attitudes toward mathematics were measured by the Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976). The subscales are Confidence in Learning Mathematics, Teacher, Usefulness of Mathematics, Mother, Attitude toward Success in Mathematics, Effectance Motivation, Father, and Math as a Male Domain. A high subscale score indicates a positive attitude toward mathematics, and a low subscale score indicates a negative attitude toward mathematics. In the Math as a Male Domain scale, a high score indicates less stereotyping of mathematics as a male domain.

Parent attitudes toward math as a male domain were measured by each parent's responses to the Math as a Male Domain Scale of the Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976). Parent perceptions of their child as a learner of mathematics were measured by each parent's responses to an adaptation of the Mother Scale (for the mother or female guardian) or to an adaptation of the Father Scale (for the

father or male guardian). The adaptation of the Mother Scale (similarly, the Father scale) consisted of rewriting the statement to reflect the mother's attitude toward her child as a learner of mathematics. For example, an item on the Mother Scale such as "My mother thinks I'm the kind of person who could do well in mathematics" was rewritten for the parent version to read "I think my child is the kind of person who could do well in mathematics."

Continuation in the math study sequence was measured by students' self reporting, as twelfth graders, of the high school mathematics courses successfully completed or to be completed that year. The data were ordinally scaled to reflect the highest level of mathematics course successfully completed or under completion. The scale was 1 (pre-algebra); 2 (algebra I); 3 (geometry); 4 (algebra II); 5 (trigonometry and/or analytic geometry); and 6 (calculus).

Data collection

Data were collected at both the eighth grade and twelfth grade by a team of researchers, each team led by one of the authors. The instruments were administered during class time; mathematics achievement and sex data were obtained from school files. Parental permission was obtained for the students to participate in the study at grade 8 and again at grade 12. Parent questionnaires, administered at grade 8, were taken home and returned to the school by the students.

Data analysis

The pattern of causal relations hypothesized among continuation in the math study sequence, student attitudes, math achievement, spatial visualization skills, parent attitudes, and parent perceptions is displayed in Figure 1. Continuation in

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Insert Figure 1 about here

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the math study sequence, student attitudes, math achievement, and spatial visualization skills were assumed to be endogenous variables whereas parent attitudes toward math as a male domain and parent perceptions of the child as a learner of mathematics were assumed to be exogenous variables. Each endogenous variable was conceived of as a linear combination of exogenous and/or endogenous variables in the model and a residual. Exogenous variables were treated as "givens." Moreover, when exogenous variables were correlated among themselves, these correlations were treated as "givens" and remain unanalyzed.

Further assumptions were a) that there was a one-way causal flow in the system (as indicated by the arrows in Figure 1) and b) that each residual was not correlated with the variables that preceded it in the model. It followed that the residuals were not correlated among themselves. Under such assumptions, the method of path analysis reduces to the solution of one or more multiple linear regression analysis (Pedhazur, 1982). Each endogenous variable is represented by an equation consisting of

the variables upon which it is assumed to be dependent and a term representing residuals or variables not under consideration in the given model. For each independent variable in the equation, there is a path coefficient indicating the amount of expected change in the dependent variable as a result of a unit change in the independent variable (assuming that all variables are standardized).

For the system in Figure 1, let z_i be defined as the z-score of the variable associated with the notation i in the figure. For example, z_1 is the z-score for the mother's attitude toward mathematics as a male domain; z_2 is the z-score for the mother's perception of the child as a learner of mathematics; etc. The symbol p_{ij} will denote the path coefficient indicating the fraction of the standard deviation of the ith variable caused by the jth variable. The symbol, e_i, $1 \leq i \leq 15$, denotes a residual or variables not included in the model. The set of equations defining the causal relations depicted by the system in Figure 1 is the following:

$$z_i = e_i, \quad 1 \leq i \leq 4 \tag{1}$$

$$z_i = p_{i1}z_1 + p_{i2}z_2 + p_{i3}z_3 + p_{i4}z_4 + e_i, \quad 5 \leq i \leq 14 \tag{2}$$

$$z_{15} = p_{15,1}z_1 + p_{15,2}z_2 + \cdots + z_{15,14}z_{14} + e_{15}. \tag{3}$$

It can be shown that the path coefficients in Equations (1), (2) and (3) are the standardized regression coefficients (β's) obtained in ordinary regression analysis. The important

difference between the two approaches is that in ordinary regression analysis a dependent variable is regressed in a single analysis on all the independent variables under consideration, but in path analysis, at each stage, a variable taken as endogenous (dependent) is regressed on the variables on which it is assumed to depend. The calculated β's are the path coefficients for the paths leading from the particular set of independent variables to the dependent variable under consideration. One of the advantages of path analysis is that it affords the decomposition of correlations among variables thereby enhancing the interpretation of relations as well as the pattern of the effects of one variable on another (Pedhazur, 1982).

The multiple linear regression analyses were performed using stepwise regression analysis (SAS Institute, 1982) with forward selection and with entry and stay level of .05. Stepwise regression analysis was chosen because of the decision of the researchers to obtain and test data-guided reduced causal models in the exploratory stages of the study. The decision to plan to test the causal model carried an inherent assumption that the models would be overidentified. The original statistics are always reproduced if the causal model is just-identified.

The causal model tested contained only the paths which satisfied the following two criteria:

1. Identified by the stepwise regression analysis to have path coefficients significantly different from zero;

2. Forming part or whole of a path from the parent variables to continuation in the math study sequence.

The method of reproduced correlations (Pedhazur, 1982) was chosen as a method of studying whether the model was consistent with the data. In reproducing correlations, the correlation coefficients between the exogenous variables are taken as given. The defining equations of the model, equations similar to (1), (2), and (3), are substituted in the formula for the zero-order correlation coefficient

$$r_{ij} = (1/N) \sum z_i z_j$$

in order to obtain the reproduced correlation, $*r_{ij}$. For example, if

$$z_4 = p_{41}z_1 + p_{42}z_2 + p_{43}z_3 + e_4$$

then

$$*r_{14} = (1/N) \sum z_1 z_4 = p_{41} + p_{42}r_{12} + p_{43}r_{13}$$

where $r_{ij} = *r_{ij}$ if both z_i and z_j are endogenous. There is no statistical measure of the appropriate "closeness" of $*r_{ij}$ to r_{ij}.

Results and discussion

Table 1 contains the means, standard deviations, and correlation coefficients for the study variables. The statistics presented in Table 1 are for males and females separately.

Insert Table 1 about here

Significant paths

The data-guided reduced causal models resulting from the regression of each of the endogenous variables are shown in Figure 2, for males, and Figure 3, for females. Only the path coefficients which are significantly different from zero are presented. R-square is the percentage of variance of each endogenous variable accounted for by the variables which precede it in the data guided models. The R-square value is listed under each endogenous variable.

Insert Figure 2 about here

Insert Figure 3 about here

The results of the path analysis indicate that the hypothesized model gives rise to different causal paths for each of males and females. The significant path, for males, from the mother's attitude toward math as a male domain to usefulness to continuation in the math study sequence can be interpreted to indicate that the mother's attitude that math is a male domain directly affects the son's attitude that math is useful; this, in turn, influences the son to continue in the math study sequence. Similarly, the mother's high perception of her son as a learner of mathematics has a direct effect on the son's high achievement as well as on his positive attitude that mathematics

is useful; each of these, in turn, contributes positively to the son's continuation in the math study sequence. The path from the father's perception of his son as a learner of mathematics to usefulness to continuation in the math study sequence has a similar interpretation.

The integral position of the male student's attitude toward the usefulness of mathematics is consistent with much of the literature. Pedro, Wolleat, Fennema, and Becker (1981) found usefulness of mathematics to be a significant predictor of the mathematics plans of 9th and 10th grade males. Lantz and Smith (1981) found that the perception of the amount of math necessary for one's chosen career was highly related to the intention to participate in nonrequired math courses. Furthermore, Parsons, Adler, and Kaczala (1982) reported that parents of sons, as compared to parents of daughters, felt that math was more important than other subjects for their child. Note should be taken that there are no significant paths through usefulness in the causal model for females.

Parsons, Adler, and Kaczala (1982) suggested that mothers have the stronger influence on the children's achievement beliefs and attitudes. The findings of this study are consistent with such a conclusion; i.e., for each of males and females, there is a significant path from the mother's perception of the child as a learner of mathematics through achievement to continuation in the math study sequence. Contrary, however, to their conclusion that the father has

little influence over and above that which is shared with the mother, we find evidence of significant father effects through usefulness to continuation in the mathematics study sequence in the model for males and of significant father effect through a) the daughter's perception of her father's perception of her as a learner of mathematics and b) the daughter's spatial skills to continuation in the math study sequence in the model for females.

Sherman (1981) found spatial skills to be the more important factor related to female continuation in the mathematics study sequence. Perl (1982) found spatial skills to be one of the factors which discriminate between female electors and non-electors of mathematics courses. The significant paths from father to spatial skills to continuation in the math study sequence for females indicate that spatial skills do influence continuation in the math study sequence and furthermore that it is the father's perception of the daughter as a learner of mathematics that influences the spatial skills.

Insert Table 2 about here

Insert Table 3 about here

Reproduced correlations

Tables 2 and 3 contain the original and the reproduced correlation coefficients for the variables identified by the causal models of Figures 2 and 3, respectively. In Table 2, there would appear to be a considerable difference between r_{14} and $*r_{14}$, between r_{45} and $*r_{45}$, and between r_{36} and $*r_{36}$. The other reproduced correlations appear to be reasonably close to their original values. The conclusion that some correlation coefficients did not reproduce indicates that the model is not as consistent with the data as might be desired. A direct effect from usefulness to achievement or vice versa may improve the model. The existence of such a direct effect, however, must be rooted in the causality theory relating the two variables and not in the more accurate reproduction of correlation coefficients.

Several of the reproduced correlations in Table 3 differ considerably from the original correlations. The reproduced correlations involving the student's perceptions of the father's perceptions, the student's spatial skills, and the student's math achievement appear to be the more inconsistent. Thus, it would appear that there should exist direct effects between some pairs of these variables.

The method of reproduced correlations has identified certain possible inconsistencies within each of the causal models derived. In fact, there would appear to be reason to investigate a causal relationship between and among student attitudes, achievement, and spatial skills.

Conclusions and implications

The study has presented a hypothesized causal model of continuation in the mathematics study sequence. The basis for the causal structure of the model lies in the theoretical studies of continuation in the math study sequence and of the cognitive and affective mathematics related variables associated with continuation in the math study sequence. The techniques of stepwise regression analysis provided data-guided models for each of males and females. The models reflected several causal paths from parent variables to continuation in the mathematics study sequence.

The primary conclusion of this study was, however, that the methods of path analysis have potential in the study of causal models of continuation in the math study sequence. It must be remembered that the methods of path analysis cannot be used to formulate causal models but can only assert that a model is consistent or inconsistent with the data. The formulation of the model must be theory-directed.

The researchers propose further study of the inconsistencies of the causal models discussed. They also propose refinement of the study variables by factor analysis with subsequent path analysis involving the resultant factors.

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Table 1

Correlations, Means, and Standard Deviations of Variables

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) Mother-Male Domain	-	.55[a]	.44	.39	.00	.11	.10	.25	.08	.00	.19	.27	.12	.05	.16
(2) Mother's Perception	.54[b]	-	.39	.51	.33	.24	.21	.39	.11	.17	.30	.17	.26	.16	.30
(3) Father-Male Domain	.38	.16	-	.65	-.03	.13	.05	.19	-.01	-.05	.21	.21	.12	.06	.18
(4) Father's Perception	.31	.46	.46	-	.19	.26	.17	.24	.13	.13	.41	.23	.21	.17	.27
(5) Confidence	.10	.35	.02	.27	-	.50	.53	.39	.40	.64	.40	.22	.32	.19	.33
(6) Teacher	.11	.28	.04	.26	.56	-	.53	.52	.51	.48	.49	.33	.29	.13	.23
(7) Usefulness	.00	.32	.02	.38	.53	.53	-	.53	.49	.56	.49	.40	.26	.17	.26
(8) Mother	.08	.35	.01	.24	.57	.58	.68	-	.49	.39	.69	.40	.29	.12	.29
(9) Att. Toward Success	.09	.30	.03	.29	.44	.50	.51	.50	-	.44	.42	.42	.18	.17	.18
(10) Effectance Motivation	-.03	.21	-.04	.15	.57	.51	.49	.47	.39	-	.34	.23	.28	.22	.18

(Table 1 continues on next page)

Correlations, Means, and Standard Deviations of Variables (Continued)

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(11) Father	.06	.24	.02	.35	.53	.58	.65	.70	.50	.47	-	.37	.24	.14	.33
(12) Math as Male Domain	.11	.24	.12	.20	.40	.48	.37	.42	.38	.35	.34	-	.37	.17	.35
(13) Math Achievement	.13	.36	.06	.27	.51	.41	.34	.39	.27	.27	.37	.28	-	.50	.64
(14) Spatial Visualization	.24	.27	.12	.23	.25	.22	.32	.22	.12	.23	.21	.10	.37	-	.48
(15) Cont./Math Study Seq.	.16	.37	.04	.29	.48	.38	.38	.37	.21	.32	.37	.29	.68	.34	-
M[c]	4.49	4.13	4.27	4.20	3.66	3.52	3.92	3.91	4.15	3.38	3.90	4.41	58.60	24.93	3.24
SD[c]	.48	.58	.59	.57	.75	.53	.63	.59	.55	.69	.64	.55	23.46	9.12	1.67
M[d]	4.37	4.19	4.22	4.24	3.79	3.49	3.90	3.98	4.00	3.26	3.92	3.80	59.85	26.13	3.49
SD[d]	.46	.46	.58	.51	.71	.59	.69	.61	.63	.74	.70	.69	25.65	9.96	1.63

[a]Upper triangle shows correlations from female data N = 213; $r \geq .14$, $p < .05$; $r \geq .17$, $p < .01$.

[b]Lower triangle shows correlations from male data N = 244; $r \geq .14$, $p < .05$; $r \geq .17$, $p < .01$.

[c]Means and standard deviations from female data.

[d]Means and standard deviations from male data.

Table 2

Original and Reproduced Correlations for the Data Guided Causal Model of Continuation in the Math Study Sequence for Males

	Variable	1	2	3	4	5	6
(1)	Mother-Male Domain	-	.54[a]	.31	.00	.13	.16
(2)	Mother's Perception	.54[b]	-	.47	.32	.36	.37
(3)	Father's Perception	.31	.47	-	.38	.27	.29
(4)	Usefulness	-.29	.34	.34	-	.34	.38
(5)	Math Achievement	.19	.36	.17	.12	-	.68
(6)	Cont./Math Study Seq.	.08	.29	.17	.25	.69	-

[a]The original correlations are reported in the upper half of the matrix.

[b]The reproduced correlations are reported in the lower half of the matrix.

Table 3

Original and Reproduced Correlations for the Data Guided Causal Model of Continuation in the Math Study Sequence for Females

	Variable	1	2	3	4	5	6
(1)	Mother's Perceptions	-	.51[a]	.30	.16	.26	.30
(2)	Father's Perceptions	.51[b]	-	.41	.17	.21	.27
(3)	Father	.20	.39	-	.14	.24	.33
(4)	Spatial Visualization	.08	.15	.06	-	.50	.48
(5)	Math Achievement	.24	.12	.05	.02	-	.64
(6)	Cont./Math Study Seq.	.07	.15	.20	.23	.53	-

[a]The original correlations are reported in the upper half of the matrix.

[b]The reproduced correlations are reported in the lower half of the matrix.

Figure Captions

Figure 1. Causal model indicating hypothesized causal relationships among the study variables.

Figure 2. Causal model of continuation in the mathematics study sequence for males. ([a]All paths are significant at $p < .05$. [b]Standardized beta weights are shown on each path. [c]R^2 is the percent of variance accounted for on each criterion measure by all preceding predictor variables.)

Figure 3. Causal model of continuation in the mathematics study sequence for females. ([a]All paths are significant at $p < .05$. [b]Standardized beta weights are shown on each path. [c]R^2 is the percent of variance accounted for on each criterion measure by all preceding predictor variables.)

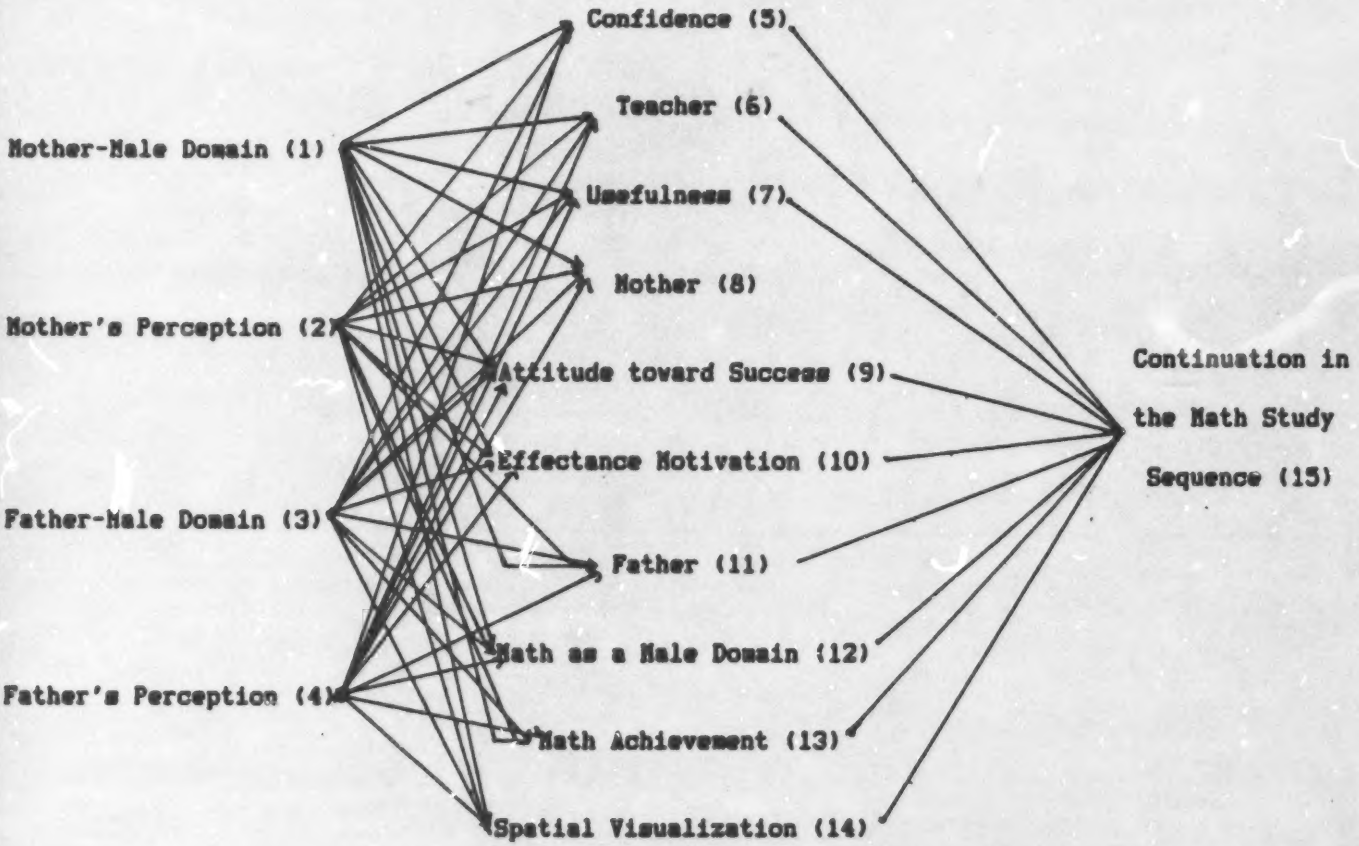
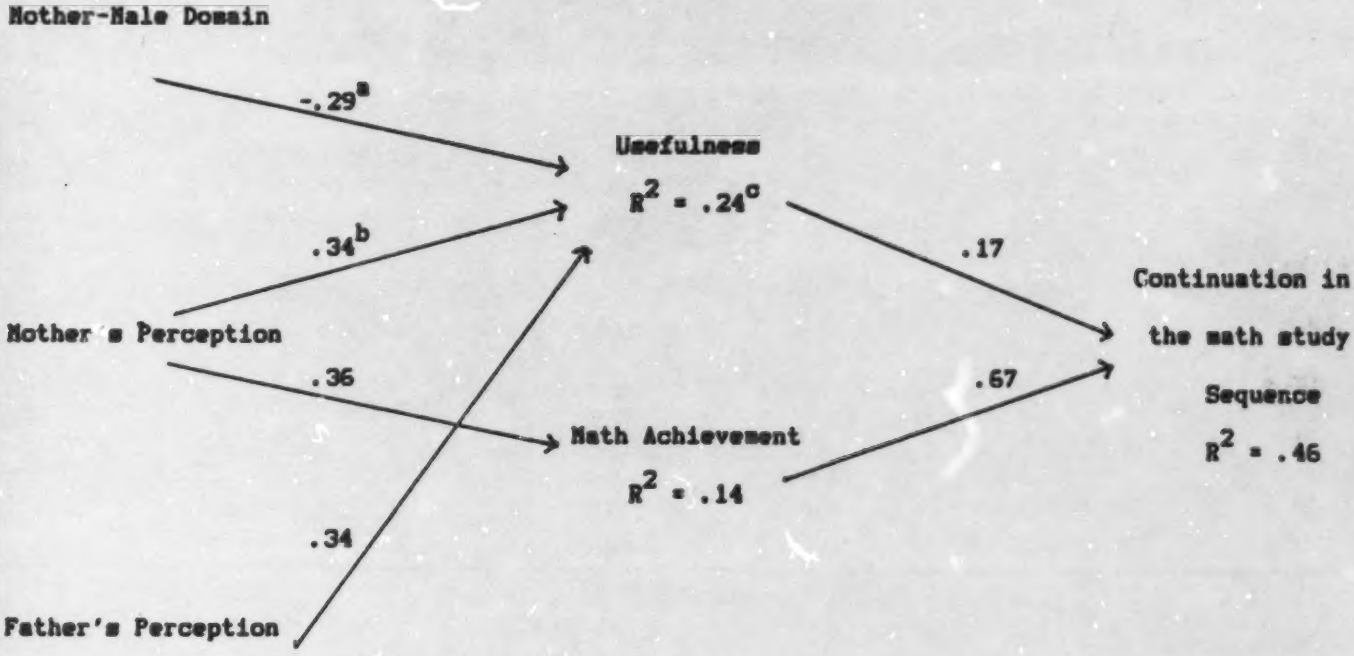

Confidence (5)
Teacher (6)
Mother-Male Domain (1)
Usefulness (7)
Mother (8)
Mother's Perception (2)
Attitude toward Success (9)
Continuation in
the Math Study
Sequence (15)
Effectance Motivation (10)
Father-Male Domain (3)
Father (11)
Math as a Male Domain (12)
Father's Perception (4)
Math Achievement (13)
Spatial Visualization (14)

Figure 1

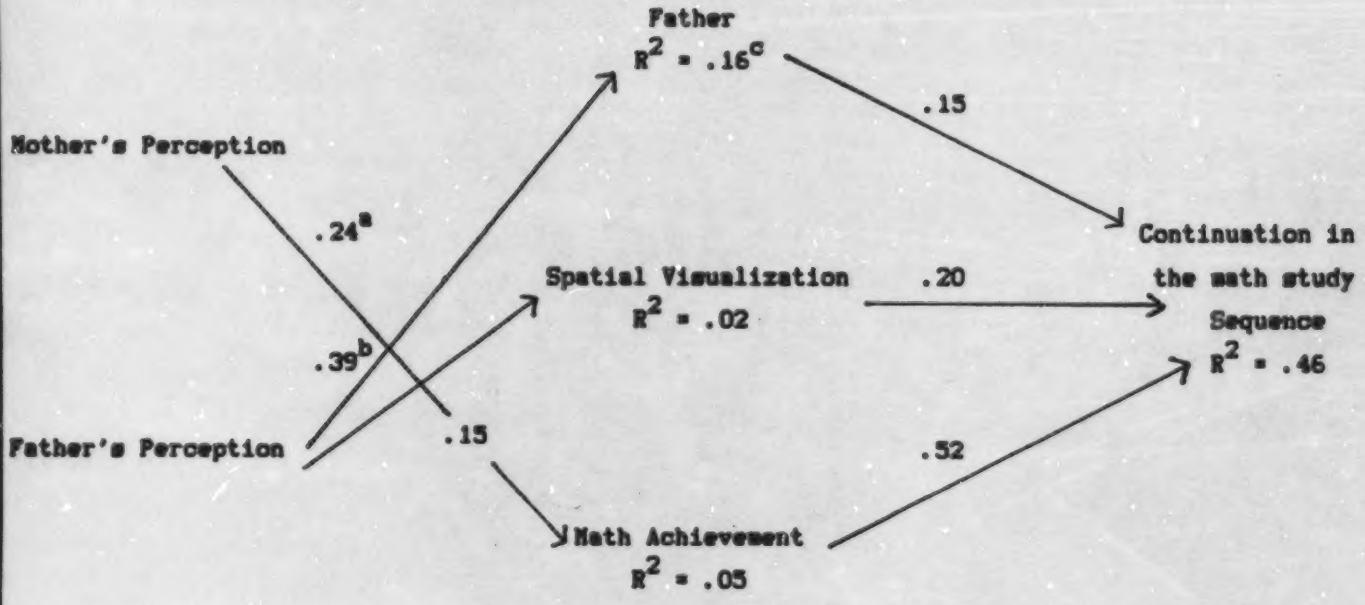


[a]All paths significant at $p < .05$.

[b]Standardized beta weights are shown on each path.

[c]R^2 is the percent of variance accounted for on each criterion measure by all preceding predictor variables.

Figure 2



[a]All paths significant at $p < .05$.

[b]Standardized beta weights are shown on each path.

[c]R^2 is the percent of variance accounted for on each criterion measure by all preceding predictor variables.

Figure 3